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RADIATED SIGNAL MEASURING DEVICE FOR RADIOGRAPHIC IMAGING EQUIPMENT

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RELATED APPLICATION

The present application is based on a prior filed provisional patent application that was filed April 16, 2001, and with the named inventor being Steven C. Tankersley.

FIELD OF THE INVENTION

The present invention relates generally to the field of radiographic imaging equipment and specifically to radiated signal measuring device for determining source to image receptor distance.

BACKGROUND OF THE INVENTION

The radiographic imager (colloquially known as an x-ray machine) is a well known and widely used diagnostic tool in medical facilities, research laboratories, airport security devices, and other applications. In essence, a radiographic imager comprises a radiation beam source and a radiographic image receptor. The radiation beam source produces a beam of high-energy electromagnetic waves, or x-rays, at a fixed or controllable intensity. Radiation from the radiation beam source passes through a collimator that limits or shapes the radiation beam to the desired area. The high-energy radiation beam passes through a subject, *e.g.*, a human anatomical appendage, and subsequently strikes the radiographic image receptor, which forms an image in response to the relative intensities of the incident radiation. The image receptor may comprise a cassette containing radiographic film, a focal plane array of electro-optic elements, or other suitable receptor.

Due to the technological complexity of the radiographic imaging process, and the potential hazards associated with exposure to the radiation, radiographic imaging equipment is maintained and operated by specially trained radiologic technologists. Prior to initiating radiation exposure to obtain a radiographic image, the technologist monitors and adjusts several critical parameters of the radiographic equipment. In particular, the voltage and current applied to the radiation beam source (and hence its intensity), the duration of exposure, and the Source-to-Image receptor Distance (SID) are critical to obtaining a radiographic image of diagnostic quality.

Since the intensity of radiation incident upon the radiographic imaging receptor changes with SID according to the Inverse Square Law, even slight variations from the optimal SID may have a profound impact on radiographic density, and hence on the quality of the resulting radiographic images. Errors in the measurement of the SID can result in radiographic image being overexposed or underexposed, with resulting distortion or misrepresentation of the anatomy depicted. If the resulting image is not of diagnostic quality, a repeat examination is required, exposing the patient to additional radiation.

Modern medical radiographic imaging equipment includes various actuators and detent switches designed to precisely position the radiation beam source in relation to the image receptor, when the subject can be positioned in a predetermined location and orientation (*e.g.*, on an integral table). However, this positioning and orientation of the subject according to predetermined parameters is not always possible. For example, patients often need x-rays in response to various injuries, which may prevent the patient from assuming a preferred position on the x-ray table. To accommodate such

applications, modern medical radiographic imaging equipment includes a variety of pivoting, sliding, and gimbaled mounting apparatuses, which allow for a large degree of variation in the configuration of the radiation source and the radiographic imaging receptor. However, in any configuration other than the predetermined ones, the radiologic technologists may not be able to take advantage of the SID measurement and control capabilities of the radiographic imaging equipment. Additionally, portable units lack such integral SID controls. In such cases, the radiologic technologist must often resort to relatively crude tools, such as traditional tape measure, to ascertain and control the SID. This method is prone to error, and is imprecise even when properly performed. Consequently, the SID of the radiographic equipment may not be properly set for each exposure.

Hence, a need exists in the art for an accurate and reliable method of measuring and indicating the Source to Image Receptor Distance in radiographic equipment.

SUMMARY OF THE INVENTION

The present invention relates to a measuring device for determining the distance between two selected points associated with a radiographic imager. The measuring device includes a radiated signal source positioned at a first point and operative to project a radiated signal. The radiated signal is detected by a detector positioned at a second point. A circuit connected to the radiated signal source and the detector determines the travel time of the radiated signal. Based on the spatial relationship between the radiated signal source, the detector, the radiographic imager radiation beam source, and the radiographic image receptor, the source to image receptor distance of the radiographic imager is determined. A display may be connected to the

control circuit to output the source to image receptor distance, which display may be periodically or continuously updated. The radiated signal may comprise a laser beam, an ultrasonic signal, a magnetic field, or an RF electromagnetic signal.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a perspective view of a representative medical diagnostic radiographic imager;

Figure 2 is a block diagram of a radiated signal SID measurement device, according to one embodiment of the present invention;

Figure 3 is a schematic representation of the reflected signal path of the radiated signal of the present invention, according to one embodiment thereof.

DETAILED DESCRIPTION OF THE INVENTION

A radiographic imager utilized for medical diagnostic imaging under restrictive circumstances is depicted in Figure 1 and indicated generally by the numeral 10. A radiation beam source and control electronics are contained in a collimator housing 12. A patient 11, due to a possible head, neck, and/or back injury, is unable to stand at a vertical chest stand, the traditional position preferred for the image depicted, a trauma lateral of the cervical spine. Consequently, the collimator housing 12 is adjusted to a lowered, horizontal position, and the patient 11 remains supine, *e.g.*, on a stretcher. A radiographic image receptor 14, in this case, a cassette containing radiographic film, is positioned on the other side of the patient's 11 cervical spine. This specific configuration of the radiographic imager 10 is illustrative only, and represents one of many possible configurations in which the SID may need to be determined and

adjusted.

To obtain radiographic images using the radiographic image equipment 10, a radiologic technologist must precisely orient the collimator housing 12 in relation to the radiographic image receptor 14, ensuring that the two are spaced apart a precise distance, which depends in general on the type of radiographic examination being conducted, the intensity of the radiation beam source, and the duration of exposure. In situations such as that depicted in Fig. 1, this Source-to-Image receptor Distance (SID) is typically measured with a tape measure or similar calibrated measuring device, or alternatively using a field size scale selector.

According to the present invention, the SID of a radiographic imager is measured by an associated distance-measuring device comprising a radiated signal source, a compatible signal detector, and an associated control circuit. The travel time of the radiated signal from the radiated signal source to the detector is measured, and the distance from the radiated signal source to the detector is determined from this travel time. The SID of the radiographic imager is then determined from the radiated signal source-to-detector distance, depending on the spatial configuration of the radiated signal source and detector in relation to the radiographic image receptor.

The distance-measuring device of the present invention may employ a broad variety of technologies to generate and detect the radiated signal. The radiated signal may, for example, comprise a laser beam, either a visible light or infrared laser. The laser beam source may comprise a gas discharge tube or a laser Light Emitting Diode (LED). The detector may comprise a photo-diode responsive to the relative frequency of the laser beam, a charge-coupled imaging device, or the like. Alternatively, the

radiated signal may comprise an ultrasonic acoustic signal, with a suitable ultrasonic source and detector, as are well known in the art. As another example, the radiated signal may comprise a Radio Frequency electromagnetic wave, such as an X or K band radar signal, with the associated source and detector comprising appropriately configured and tuned oscillators, transmitters, receptors, and antennas, as are well known in the art. Particularly for the measurement of small distances, the radiated signal may comprise a magnetic flux, for example generated by an electromagnet and detected by a Hall effect sensor. In general, a wide array of radiated signal measuring devices are known in the art, and may be advantageously adapted to the SID measuring device of the present invention.

In one exemplary embodiment, the SID measuring device of the present invention comprises a laser rangefinder, a block diagram of which is depicted in Figure 2 and indicated generally by the numeral 100. The measuring device 100 comprises a laser source 102, a laser light detector 104, a controller 106, and a display 108. The laser source 102 and controller 106 are powered by a power supply 110, selectively coupled to the source 102 via switch 112. The laser source 102 may comprise a laser gas discharge tube, such as for example, a helium-neon (He-Ne) laser tube, with suitable high power electronics and control circuitry. Alternatively, the laser source 102 may comprise any of a broad array of available laser LEDs and suitable associated drive electronics. The laser source 102 may emit laser light within the human visible spectrum, or alternatively may emit an infrared laser beam. Laser light detector 104 may comprise a photo-diode responsive to the frequency of the laser beam emitted by the laser source 102. The detector 104 may additionally include appropriate associated

thresholding and drive electronics.

Both the laser source 102 and the laser light detector 104 are connected to, and operate under the control of, controller 106. Control circuit 106 may in general be implemented in a broad variety of ways. In one embodiment, controller 106 includes a digital microprocessor, microcontroller, or digital signal processor, the operation of which may be specified by a software program. The controller 106 receives a high-frequency periodic oscillating signal, or “clock” signal, from an oscillator 107. Based on the known frequency of the oscillator 107, the controller 106 is operative to measure the elapsed time from the initiation of a laser beam projected from the source 102 until the detection of that beam incident upon the laser detector 104. The power supply 110 provides appropriate electrical power to both the laser source 102 and the controller 106. In one embodiment, the power supply 110 is coupled to the source 102 via a switch 112, operated by the radiologic technologist. This allows the laser source 102 to be energized only when the technologist is positioning the collimator housing 12 relative to the radiographic image receptor 14 in preparation for a radiographic exposure. This selective control reduces any potential vision hazard associated with the laser source 102, and in the case of a visible laser beam, may alleviate potential apprehension on the part of the diagnostic patient.

In one embodiment, a display 108 is connected to and controlled by the controller 106, and is operative to display the radiographic imager SID to the radiologic technologist. The display is preferably continuously updated to reflect instantaneous changes in the SID as the technologist positions the collimator housing 12. The SID may be displayed in any appropriate units, under the control of controller 106. The

display 108 may comprise a Liquid Crystal Display (LCD) of a suitable size and configuration, a series of seven-segment LED display characters, or other electronic numerical display as are well known in the art. Alternatively, in radiographic imaging equipment containing a separate display or interface, *e.g.*, whereby the radiologic technologist may monitor and control parameters of the radiation source such as voltage and current, the display 108 may comprise an interface circuit compatible with said existing display, such that the SID display is integrated with the other radiographic equipment information.

The radiated signal source 102 and the detector 104 of the radiated signal SID measuring device of the present invention may be arranged in a variety of ways to effect measurement of the SID. The radiated signal source 102 may be affixed to the exterior of the collimator housing 12 of the radiographic imager 10 (see Fig. 1) via a moveable bracket, allowing the radiated signal to be independently directed, or "aimed," to any specific desired point. In this configuration, the distance from the radiated signal source 102 to the radiation beam source within the collimator housing is fixed and known, and can be easily accounted for in the SID calculations. Alternatively, the radiated signal source 102 may be mounted in the interior of the collimator housing 12, either coincident with or a known distance from the radiation beam source. Two basic configurations of the radiated signal source 102 and detector 104 are contemplated (each dictating a difference placement of the detector 104): a direct distance measurement and a reflected measurement.

In a direct distance measurement, the radiated signal source 102 is fixed in a known spatial relationship with the radiation beam source, such as for example, affixed

to the collimator housing 12. The detector 104 is positioned on or adjacent the radiographic image receptor 14, such as for example, embedded in or clipped onto a radiographic film cassette. The radiated signal source 102 and detector 104 are aligned such that the radiated signal (*e.g.*, the laser beam) travels in a straight line from the radiated signal source 102 to the detector 104. In this configuration, calculation of the SID is simply the measured travel time of the radiated signal from the radiated signal source 102 to the detector 104, multiplied by the known propagation speed of the radiated signal (*e.g.*, 3×10^8 m/sec for a laser beam). Mathematically,

$$SID = t_{travel} * s_{prop} \quad \text{where}$$

SID = Source to Image receptor Distance;

t_{travel} = travel time of the radiated signal from the radiated signal source to the detector; and

s_{prop} = propagation speed of the radiated signal.

In a reflected configuration, both the radiated signal source 102 and the detector 104 are affixed in a known spatial relationship to the radiation beam source, such as for example, affixed to the collimator housing 12. The radiated signal is in this case directed from the radiated signal source 102 to a surface substantially in the plane of the radiographic image receptor, for example, a radiographic film cassette, in a region that is not occupied by the anatomy of the diagnostic subject. In situations where the diagnostic subject covers substantially all of the radiographic image receptor, the radiated signal may be reflected off of an adjacent surface, substantially coplanar with the radiographic image receptor, such as for example, a stretcher or back board. In this configuration, the radiated signal is directed from the radiated signal source 102 to the

plane of the diagnostic image receptor 14, and is reflected to the detector 104. In general, the radiated signal source 102 and detector 104 need not be coplanar with respect to the radiographic image receptor 14. This arrangement is depicted in Figure 3.

In this configuration the SID is calculated by first determining the path length of the radiated signal, indicated as *p*. As in the case of direct illumination, the distance *p* is given by multiplying the travel time of the radiated signal from the radiated signal source 102 to the image receptor 14 and thence to the detector 104, multiplied by the propagation speed of the radiated signal. The known offset of the radiated signal source 102 and detector 104, if any, indicated by the quantity d_{sd} in Figure 3, is subtracted from the signal path length *p* (regardless of whether the radiated signal source 102 or detector 104 is positioned closest to the image receptor 14). The remaining distance *x* is then half of the remaining path length. Finally, the SID is the radiated signal source-to-detector offset (if any) plus the quantity *x*. Note that this calculation assumes that the angle θ formed between the incident and reflected radiated signal path is small. In this case, *sin* θ is negligible, and does not affect the calculation of *p* as described. For a wider angle θ, one of skill in the art may easily derive distance calculation equations to account for the angle. Mathematically,

$$p = t_{travel} * s_{prop}$$

$$x = \frac{p - d_{sd}}{2} \quad \text{and}$$

$$SID = x + d_{sd} \quad \text{where}$$

p = radiated signal path length from radiated signal source to detector;

t_{travel} = travel time of the radiated signal from the radiated signal source to the detector;

s_{prop} = propagation speed of the radiated signal;

d_{sd} = distance of offset between radiated signal source and detector in direction of image receptor;

x = distance between the image receptor plane and the closer of the radiated signal source and detector; and

SID = radiation beam source to mage receptor distance;

By use of the radiated signal measuring device of the present invention, the SID of a radiographic imager may be easily and accurately set prior to each exposure, particularly in situations where the SID setting facilities of the radiographic imaging equipment may not be fully utilized. This increases the quality of the resulting diagnostic image by ensuring the proper relationship between the radiation beam energy (*e.g.*, as controlled by the radiologic technologist by varying the voltage and current applied to the radiation beam source), the image receptor type, the SID, and the characteristics of the imaging subject.

Although the present invention has been described herein with reference to a diagnostic medical radiographic imager, one of skill in the art will readily recognize that the invention is not so limited; it may be advantageously applied to improve the accuracy and quality of any radiographic imaging equipment. For example, and without limitation, the SID measuring device may be used in portable and field-deployed radiographic imagers utilized by emergency medical personnel and the military, in particular in situations where radiographic imaging must be performed on a stretcher, hospital bed or immobilization device such as a backboard used to transport trauma

victims. In these situations, a separate physical measuring device may be misplaced or broken, and even if maintained in operable condition, represents an additional piece of equipment that must be stored, transported and inventoried. The present invention may also be advantageously utilized in surgical situations, where a patient's location and orientation may be restricted, and where the introduction of physical measuring devices such as scales and standards may contaminate the sterile field.

Furthermore, the present invention finds utility in research and laboratory applications, where the subject matter may require varied configurations of the radiographic image equipment, and where SID accuracies more precise than those obtainable with conventional measuring devices are required. As yet another example, the present invention may be useful in various security and law enforcement applications, such as airport terminals, border crossings, diplomatic installations, and the like. Such applications encompass both fixed radiographic imagers, such as luggage inspection, and portable units, such as those used by bomb squads and contraband inspectors. In both fixed and portable radiographic imaging equipment, quick, accurate positioning of the radiation beam source and image receptor, without the use of external devices, is advantageous.

Although the present invention has been described herein with respect to particular features, aspects and embodiments thereof, it will be apparent that numerous variations, modifications, and other embodiments are possible within the broad scope of the present invention, and accordingly, all variations, modifications and embodiments are to be regarded as being within the spirit and scope of the invention. The present embodiments are therefore to be construed in all aspects as illustrative and not

restrictive and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.